National Center for Environmental Research and Quality Assurance

NCERQA Grant Final Report Summary

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Title: Measurement and source Apportionment of Human Exposures to Toxic Air Pollutants in the Minneapolis-St. Paul Metropolitan Area

Investigators: 1. Dr. Gregory Pratt
2. Dr. Ken Sexton
3. Dr. Tom Stock

Institution: 1. Minnesota Pollution Control Agency
Air Quality Division
520 Lafayette Road
St. Paul, MN 55155
2. University of Minnesota
3. University of Texas

Research Category: Air Toxics

Project Period: 02/10/97 - 08/09/01

Objective of Research: The project has two major objectives: (1) to apportion the relative contributions of point, area, and mobile sources to measured ambient concentrations of selected toxic air pollutants (i.e., a suite of volatile organic compounds and $PM_{2.5}$) in three communities in the Minneapolis/St. Paul metropolitan area; and (2) to apportion the relative contributions of measured ambient (outdoor) concentrations and indoor residential concentrations to measured personal exposures for the selected air toxics in these same three communities.

Summary of Findings: Based upon a preliminary air dispersion modeling study of volatile organic compounds (VOCs) in the twin cities metropolitan area, we selected three neighborhoods for exposure monitoring (Phillips, Battle Creek, and East St. Paul—Figure 1, McCourtney et al., 1999; Pratt et al., 1998). Neighborhood monitoring sites were identified in each neighborhood and leases were established to conduct air monitoring at those locations.

A pilot monitoring study was done to evaluate the performance of the personal Organic Vapor Monitors (OVMs) under cold temperature conditions. Stock *et al.* found that OVM measurements compared favorably with canister measurements of VOCs, although the OVM measurements tended to be slightly lower than matched canister measurements.

We received additional funding from the University of Minnesota to add particle sampling to the study. A subset of study participants wore personal $PM_{2.5}$ samplers in addition to OVMs, and $PM_{2.5}$ was also measured in their homes. The neighborhood sampling sites were equipped with both PM_{10} and $PM_{2.5}$ samplers. The addition of particle sampling delayed the startup of sampling by several months.

In December, 1998 and January, 1999 we conducted a trial run in which project staff wore the sampling equipment over a period of ten days. Based upon the results of this pilot study, we made modifications to the procedures for outfitting study participants with monitoring equipment.

Beginning in January, 1999 we recruited study participants, and on April 20 we began personal montoring. Figure 2 shows a calendar of all sampling periods. Sampling ended in November, 1999. Gravimetric analyses of particle filters and GC/MS analyses of OVMs continued for about six months after sampling. Metals analyses of the personal and outdoor particle samples was attempted using XRF, but the technique was found to be inadequate (detection limits too high). These analyses are currently being done with a more sensitive methodology under a separate grant. The 1997 Minnesota VOC emissions were inventoried, and work is underway to model concentrations of the measured VOCs in the neighborhoods and at participants' homes to compare with the measured values.

The first data to be looked at were the $PM_{2.5}$ data. Some basic summary statistics from the $PM_{2.5}$ monitoring are given in Tables 1-3. The $PM_{2.5}$ participants were a subset of the VOC participants. Some of the highlights of the $PM_{2.5}$ analysis include the following:

(1) Outdoor 24-hour average concentrations were highly correlated across the three neighborhoods (Figure 3);

(2) Within-day variability for both indoor and outdoor 15-min average $PM_{2.5}$ concentrations was substantial and comparable in magnitude to day-to-day variability for 24-hr average concentrations;

(3) 15-minute average outdoor $PM_{2.5}$ concentrations varied by as much as an order of magnitude within a day;

(4) There was much greater variability in the withing-day 15-minute indoor concentrations than outdoor concentrations (as much as a factor of of ~40). This is most likely due to the influence of indoor activities that cause high short-term peaks in concentrations;

(5) Some residences exhibited substantial variability in indoor aerosol characteristics from one day to the next;

(6) Peak values for indoor short-term (15-min) average $PM_{2.5}$ concentrations routinely exceeded 24-hr average outdoor values by factors of 3–4 (Figure 4);

(7) The correlation between matched outdoor and indoor 15-minute average $PM_{2.5}$ concentrations showed a strong seasonal effect, where higher values were observed in spring and summer, and lower values in fall—mainly due to the doors and windows being open for more time during spring and summer;

(8) Indoor and outdoor $PM_{2.5}$ concentrations werestatistically significantly correlated, as were personal and indoor $PM_{2.5}$ concentrations (Table 4), although the correlations were not particularly strong (r=0.27 and r=0.51, respectively). Personal and outdoor $PM_{2.5}$ concentrations, on the other hand, were not significantly correlated (r=0.06).

(9) For 29 adults with 7-15 days of $PM_{2.5}$ monitoring we found that the distribution of longitudinal correlation coefficients between personal and indoor $PM_{2.5}$ was moderately high (median r=0.45). The distribution of longitudinal correlation coefficients between indoor and outdoor concentrations showed that these variables were less strongly associated (median r=0.25), and the distribution of personal to outdoor correlation coefficients (median r=0.02) showed little statistical relation between these two variables for a majority of participants. A sensitivity analysis indicated that these results were not improved by excluding days with exposure to environmental tobacco smoke or occupational exposures. On average these adults spent 91% of their time indoors.

(10) Changing meteorological conditions such as a frontal passage resulted in changing $PM_{2.5}$ concentrations across the region and not just at individual sites. In some cases particle removal by precipitation events was seen;

(11) Indoor concentrations were typically higher than outdoor concentrations and personal concentrations were typically higher still;

(12) A frequency distribution of all the indoor and outdoor 15-minute average concentrations is shown in Figure 5. A tri-modal lognormal distribution was fit to the outdoor distribution. The smallest mode contained 12.5% of all measurements, and had a geometric mean (GM) of 1.1 $\mu g/m^3$ and a geometric standard deviation (GSD) of 2.2. This may be interpreted as a background aerosol that is observed on clean days. The second mode contained 60.2% of all measurements and had a GM of 6.7 $\mu g/ m^3$ and a GSD of 1.6, and may be interpreted as the most commonly observed ambient aerosol and is at least a metropolitan area scale phenomenon. The third mode contained 27.2 % of all the measurements, with a GM of 20.8 $\mu g/ m^3$ and a GSD of 1.3, and may be representative of high concentrations possibly due to localized sources of $PM_{2.5}$. A bimodal lognormal distribution was fit to the indoor distribution. 14% of the measurements fell under the first mode with a GM of 8.3 $\mu g/ m^3$ and a GSD of 1.66. 86% of the measurements form a second mode with a GM of 35.9 $\mu g/ m^3$ and a GSD of 1.8. One possible interpretation of these two modes is that the first represents the influence of the outdoor aerosol on the indoor aerosol, and the second mode can be seen as the influence of indoor emissions.; and,

(13) Indoor $PM_{2.5}$ concentrations were typically higher than outdoor concentrations, and personal concentrations were typically higher still (Figure 6).

Analysis of the VOC results has only recently begun. Preliminary summary results are given in Table 5. Fifteen pollutants were detected at least once in outdoor air using personal samplers, while four pollutants (1,3-butadiene, methyl-t-butyl ether, chloroprene and p-dichlorobenzene) were not detected in outdoor air. Eighteen pollutants were detected at least once in indoor air, while methyl-t-butyl ether was not detected in indoor air. Nineteen pollutants were measured in detectable quantities at least once in personal air. In general, a greater percentage of indoor samples were above detection limits than outdoor samples, and a greater percentage of personal samples were above detection limits than indoor samples.

The pollutants found in the greatest mass in outdoor air were toluene, xylenes, and benzene (in decreasing order). In personal and indoor air the pollutants found in the largest mass quantities were toluene, d-limonene, xylenes, benzene, and ethyl benzene (in decreasing order). As with $PM_{2.5}$ indoor concentrations of most pollutants were typically higher than outdoor concentrations and personal concentrations were typically higher still.

Publications/Presentations supported wholly or partially:

McCourtney, M., G.C. Pratt, and C.Y. Wu, *"Model-Predicted Concentrations of Toxic Air Pollutants in the Minneapolis/St. Paul Metropolitan Area,"* Paper no. 98-TPB.12P presented at: Air and Waste Management Association Annual Meeting, June, 1998. (hard copy and electronic copy attached)

Pratt, G.C., M. McCourtney, C.Y. Wu, D. Bock, K. Sexton, J. Adgate, and G. Ramachandran, *"Measurement and Source Apportionment of Human Exposures to Toxic Air Pollutants in the Minneapolis-St. Paul Metropolitan Area,"* in: Measurement of Toxic and Related Air Pollutants, Proceedings of a Specialty Conference, Cosponsored by the Air and Waste Management Association and the U.S. EPA National Exposure Research Laboratory, September, 1998. (hard copy and electronic copy attached)

Phillips, C.V. and K. Sexton, *Science and policy implications of defining environmental justice,* J. Exposure Analysis and Environmental Epidemiology 9:9-17, 1999.

Perlin, S.A., K. Sexton, and D.W.S. Wong, *An examination of race and poverty for populations living near industrial sources of air pollution,* J. Exposure Analysis and Environmental Epidemiology 9:29-48, 1999.

Sexton, K. and J.L. Adgate*, Looking at environmental justice from an environmental health perspective,* J. Exposure Analysis and Environmental Epidemiology 9:3-8, 1999.

Stock,T.H., M.T. Morandi, G.C. Pratt, D. Bock and J.H. Cross, *Comparison of the results of VOC monitoring with diffusive samplers and canisters*, Presented at: Indoor Air 99 - The 8th International Conference on Indoor Air Quality and Climate, Edinburgh, Scotland, 8/8 - 8/13/99. (hard copy and electronic copy attached)

Pratt, G.C., *Air Toxics in Minnesota: Modeling and monitoring*, Presented at: Air and Waste Management Association Annual Meeting, June, 2000. (hard copy and electronic copy attached)

Pratt,G.C., K. Palmer, C.Y. Wu, F. Oliaei, C. Hollerbach, and M.J. Fenske*, An assessment of air toxics in Minnesota*, Environ. Health Perspect. 108:815-815, 2000. (hard copy attached)

Ramachandran, G., J. L. Adgate, N. Hill, K. Sexton, G.C. Pratt and D. Bock, *Comparison of Short-Term Variations (15-Minute Averages) in Outdoor and Indoor PM 2.5 Concentrations*, J. Air & Waste Manage. Assoc. 50:1157-1166, 2000. (hard copy and electronic copy attached)

Sexton, K, L.A. Waller, R.B. McMaster, G. Maldonado, and J.L. Adgate, *The Importance of Spatial Effects for Environmental Health Policy and Research, Human and Ecological Risk* Assessment 8:109-125, 2002.

Adgate, J.L., G. Ramachandran, G.C. Pratt, L.A. Waller, and K. Sexton, *Spatial and Temporal Variability in Outdoor, Indoor, and Personal $PM_{2.5}$ Exposure in Minneapolis St. Paul, MN* (submitted to J. Air Waste Manage. Assoc.).

Ramachandran, G., J.L. Adgate, G.C. Pratt, and K. Sexton, *Characterization of 15-minute average Indoor and Outdoor $PM_{2.5}$ Concentrations* (submitted to Aerosol Science and Technology).

Adgate, J.L., G. Ramachandran, G.C. Pratt, L.A. Waller, and K. Sexton, *Longitudinal Variability in Outdoor, Indoor, and Personal $PM_{2.5}$ Exposure*, (in preparation)

We are also beginning preparation of 3 manuscripts addressing the VOC measurements and modeling. Additional papers will be submitted when published.

Supplemental Keywords: Midwest, EPA Region 5, community-based, indoor air

Relevant Web Site: http://www.pca.state.mn.us/air/index.html

Table 1. Descriptive statistics for Outdoor, Indoor, and Personal $PM_{2.5}$ concentrations stratified by community and by season (all values in $\mu g/m^3$, except as indicated).

	Battle Creek						E. St. Paul						Phillips					
	N[a]	Mean	SD	GM[b]	GSD[c]	Range	N	Mean	SD	GM	GSD	Range	N	Mean	SD	GM	GSD	Range
Outdoor																		
All Seasons[d]	88	9.4	6.2	7.8	1.8	1.0-35.4	95	10.8	6.6	9.3	1.8	1.1-41.6	88	10.0	5.8	8.7	1.7	2.8-21.6
Spring	36	10.5	7.1	8.5	2.0	1.0-33.1	36	12.0	7.3	10.1	1.9	1.1-35.5	30	12.1	7.2	10.5	1.7	3.6-35.3
Summer	22	8.7	4.4	7.8	1.6	3.5-20.0	25	8.5	3.2	7.8	1.6	2.3-14.4	30	8.6	3.8	7.8	1.6	2.8-16.9
Fall	30	8.4	6.2	7.1	1.7	2.1-35.4	34	11.3	7.5	9.6	1.8	2.5-41.6	28	9.3	5.5	8.1	1.7	2.8-27.9
Indoor																		
All Seasons[e]	108	10.6	6.6	9.0	1.8	2.3-36.9	97	17.4	20.3	12.2	2.2	1.3-130	89	14.2	13.0	11.3	1.9	3.1-90.9
Spring	25	12.7	7.7	11.0	1.7	4.7-35.5	30	20.7	26.4	13.6	2.4	3.0-130	15	16.9	14.2	13.0	2.1	4.9-60.8
Summer	36	8.9	3.8	8.1	1.5	3.5-16.4	26	15.8	11.4	13.7	1.6	4.7-65.9	36	13.2	6.4	11.4	1.7	3.1-30.2
Fall	47	10.9	7.4	8.8	2.0	2.3-36.9	41	16.0	19.6	10.4	2.4	1.3-97.7	38	14.4	16.7	10.6	2.0	3.3-90.9
Personal																		
All Seasons[f]	118	22.6	25.7	16.2	2.2	3.8-207	107	30.5	38.7	20.6	2.3	2.5-298	107	26.5	24.3	20.9	2.0	2.2-211
Spring	41	26.3	25.7	19.4	2.1	3.9-133	44	33.9	34.4	23.9	2.3	2.5-201	28	37.5	37.6	30.0	1.8	14.9-211
Summer	31	28.5	36.1	20.3	2.1	5.9-207	25	20.5	15.0	17.2	1.8	5.9-82.4	40	22.6	15.3	19.2	1.7	2.7-82.3
Fall	46	15.5	13.4	11.9	2.1	3.8-80.3	38	33.1	51.9	19.5	2.5	5.0-298	39	22.6	16.7	17.6	2.1	2.2-67.5

[a]Number of valid observations
[b]Geometric Mean
[c]Geometric Standard Deviation
[d]336 total outdoor samples attempted, with 65 (19%) invalidated because of equipment failure
[e]367 total indoor samples attempted, with 62 (16.9%) indoor of filters invalidated because of pump problems (e.g., flows outside of target range), and 19 (5.2%) of samples invalidated because of filter problems (e.g., punctures, mishandling)
[f]413 total personal samples were attempted, with 38 (9.2%) filters invalidated because of pump problems (e.g., flows outside of target range, battery problems) and 44 (11%) of personal filters invalidated because of filter problems (e.g., punctures, mishandling).

Table 2. Summary of individual time-activity patterns for the $PM_{2.5}$ study participants, tobacco exposure, and household ventilation patterns. Results reported as hours per day unless otherwise indicated.

Variable	Mean	SD	Median	Min	Max
Time Sent in Microenvironment					
Indoors (all locations)	**21.6**	**2.4**	**22.0**	**10.0**	**24**
-at Home	17.2	4.7	18.0	1.0	24
-at Work/School	3.1	4.3	0.0	0.0	15.4
-at Other	1.3	1.9	0.0	0.0	9.5
Outdoors (all locations)	**2.8**	**3.6**	**1.0**	**0.0**	**15.4**
-at Home	0.7	1.4	0.0	0.0	9.0
-at Work/School	1.6	3.4	0.0	0.0	15.4
-at Other	0.5	1.3	0.0	0.0	8.5
In Transit	**1.0**	**1.0**	**0.9**	**0.0**	**8.5**
Minutes/day tobacco exposure[a]	**14**	**62**	**0**	**0**	**600**
-BCK	0.8	8.3	0	0	90
-ESP	38	102	0	0	600
-PHI	5.9	19	0	0	120
Hours of household ventilation[b] (all locations)	**9.7**	**10.4**	**4.0**	**0**	**24**
-BCK	6.9	8.9	2.0	0	24
-ESP	13.7	10.6	15.0	0	24
-PHI	9.9	10.4	4.0	0	24

[a]Measured on days with a valid personal PM2.5 measurement.
[b]Hours per day that windows and or doors open.

Table 3. Summary data for $PM_{2.5}$ 24-hr average concentrations and I/O ratios and 15-min average concentrations and I/O ratios.

Metric	Number of Calendar days	Mean	Median	Standard Deviation	10th, 90th Percentiles
24-Hr Average					
Outdoor Concentration	52[a]	10.7 μg/m³	9.3 μg/m3	6.5 μg/m3	4.0, 19.6 μg/m3
Indoor Concentration	54[b]	13.5 μg/m3	11.5 μg/m3	8.7 μg/m3	5.3, 22.5 μg/m3
Indoor/Outdoor Ratio	49[c]	1.56	1.06	2.6	
Metric	**Number of 24-hr Periods**	**Mean**	**Median**	**Standard Deviation**	**10th, 90th Percentiles**
15-Min Average[d]					
Outdoor Concentration	48[e]	10.7 μg/m3	7.5 μg/m3	10.8 μg/m3	1.2, 23.7 μg/m3
Indoor Concentration	104[f]	14.7 μg/m3	11.4 μg/m3	13.6 μg/m3	5.1, 27.9 μg/m3
Indoor/Outdoor Ratio	15[g]	2.4	1.4	3.9	0.7, 4.2

Notes:

[a]Over the 52 calendar days, 139 valid gravimetric samples were obtained in the three communities. These include many instances when multiple measurements were made on the same calendar day but at different central community sites. For 35 of the 52 calendar days, we obtained valid gravimetric measurements at all three sites, while for the other 17 calendar days we had valid measurements at two of the three sites.

[b]Over the 54 calendar days, 168 valid gravimetric samples were obtained in residences in the three communities. These included many instances when multiple measurements were made on the same calendar day but in different residences.

[c]Over the 49 calendar days, 24-hr I/O ratios were calculated for 143 24-hr sampling periods. On a given calendar day, 1-6 residences could be monitored, leading to multiple values of I/O ratios for the same calendar day.

[d]For 15-min averages, the number of 24-hr measurement periods is more relevant than the number of calendar days. Multiple measurements made on the same calendar but at different locations may display different unique temporal patterns and, hence, are considered independent.

[e]Concurrent valid outdoor DustTrak measurements were available for 48 of the 139 24-hr outdoor measurement periods and correspond to 34 calendar days.

[f]Concurrent valid indoor DustTrak measurements were available for 104 of the 168 24-hr measurement periods in residences and correspond to 52 calendar days.

[g]Concurrent valid outdoor and indoor DustTrak measurements were available for 15 complete 24-hr measurement periods. These are a subset of the 48 outdoor monitoring periods and 104 indoor monitoring periods.

Table 4. Log Correlations (r) between Outdoor (O), Indoor (I), and Personal (P) $PM_{2.5}$ concentrations.

	I-O		P-O		P-I	
	r	p=	r	p=	r	p=
All Households	0.27	<0.0001	0.06	0.29	0.51	<0.0001
By Community (All Seasons)						
BCK	0.40	<0.0001	0.02	0.85	0.37	0.0005
ESP	0.13	0.22	0.06	0.55	0.72	<0.0001
-results with one high exposure subject removed[a]	0.19	0.042	0.20	0.06	0.63	<0.0001
PHI	0.35	0.0008	0.13	0.20	0.40	0.0002
By Season (All Communities)						
Spring	0.34	0.005	0.14	0.14	0.40	0.004
Summer	0.32	0.001	0.08	0.46	0.44	<0.0001
Fall	0.20	0.03	0.03	0.76	0.60	<0.0001

[a]One ESP participant had up to 600 minutes per day of tobacco exposure recorded on their time-activity diary

TABLE 5. COMPARISON OF OUTDOOR, INDOOR, AND PERSONAL BADGE RESULTS FOR 3 SEASONS AND ALL COMMUNITIES

		% > DL			MEAN ($\mu g/m^3$)			% CV			MEDIAN ($\mu g/m^3$)			MAX ($\mu g/m^3$)		
POLLUTANT	**DET. LIMIT ($\mu g/m^3$)**	**OUT**	**IN**	**PER**	**OUT**	**IN**	**PER**	**OUT**	**IN**	**PER**	**OUT**	**IN**	**PER**	**OUT**	**IN**	**PER**
Butadiene	2.01	0.0	1.9	4.0	1.0	1.1	1.2	0	86	96	1.0	1.0	1.0	1.0	13.3	12.3
Methylene Chloride	0.78	20.8	61.8	72.9	0.5	7.4	5.9	66	591	340	0.4	1.1	1.4	2.4	743.8	291.7
Methyl-t-butyl ether	0.38	0.0	0.0	0.3	0.2	0.2	0.2	0	0	55	0.2	0.2	0.2	0.2	0.2	2.1
Chloroprene	0.35	0.0	0.9	0.3	0.2	0.2	0.2	0	14	10	0.2	0.2	0.2	0.2	0.5	0.5
Chloroform	0.23	4.2	75.7	79.4	0.1	1.5	1.6	26	130	108	0.1	0.9	1.0	0.3	15.4	11.0
Carbon Tetrachloride	0.51	68.1	56.8	69.5	0.5	0.5	0.6	44	58	51	0.6	0.5	0.6	1.0	2.4	2.7
Benzene	0.40	94.4	98.4	100.0	1.5	5.6	7.1	59	164	197	1.4	1.9	3.1	4.5	64.5	167.3
Trichloro-ethylene	0.26	18.1	37.9	49.8	0.2	0.6	1.0	80	301	408	0.1	0.1	0.1	0.8	24.3	53.2
Toluene	7.68	12.5	71.0	79.4	4.7	22.2	29.4	55	119	176	3.8	12.3	16.8	15.9	169.8	634.6
Tetrachloro-ethylene	0.48	41.7	59.3	72.6	0.6	2.7	28.6	110	319	808	0.2	0.6	0.9	3.4	97.2	2757.0
Ethyl Benzene	0.29	75.0	96.8	100.0	0.7	3.8	5.4	68	169	225	0.6	1.4	2.1	2.3	45.8	169.0
m/p-Xylene	0.86	79.2	98.4	100.0	2.4	14.1	20.1	70	175	213	2.2	4.7	7.2	8.6	166.8	557.1
Naphthalene	0.29	2.8	11.0	5.6	0.2	0.2	0.2	76	155	209	0.1	0.1	0.1	1.1	3.0	6.9
o-Xylene	0.34	75.0	97.2	99.7	0.8	4.6	6.5	70	181	207	0.7	1.5	2.3	2.9	63.6	164.4
Styrene	0.26	20.8	68.8	79.8	0.2	0.8	1.0	80	201	156	0.1	0.5	0.7	1.1	20.4	17.8
a-Pinene	0.32	22.2	89.6	90.3	0.2	5.9	5.7	90	249	212	0.2	2.1	2.3	1.7	172.7	137.9
b-Pinene	0.50	4.2	60.3	65.7	0.3	2.9	3.8	45	478	351	0.2	0.9	1.2	1.1	227.7	188.7
d-Limonene	1.06	4.2	87.7	90.3	0.6	14.5	21.0	87	175	160	0.5	7.6	10.5	4.9	268.8	233.1
p-Dichloro-benzene	0.58	0.0	20.2	38.6	0.3	1.2	3.1	0	366	370	0.3	0.3	0.3	0.3	39.6	139.9

% CV = STANDARD DEVIATION DIVIDED BY THE MEAN, CONVERTED TO PERCENT

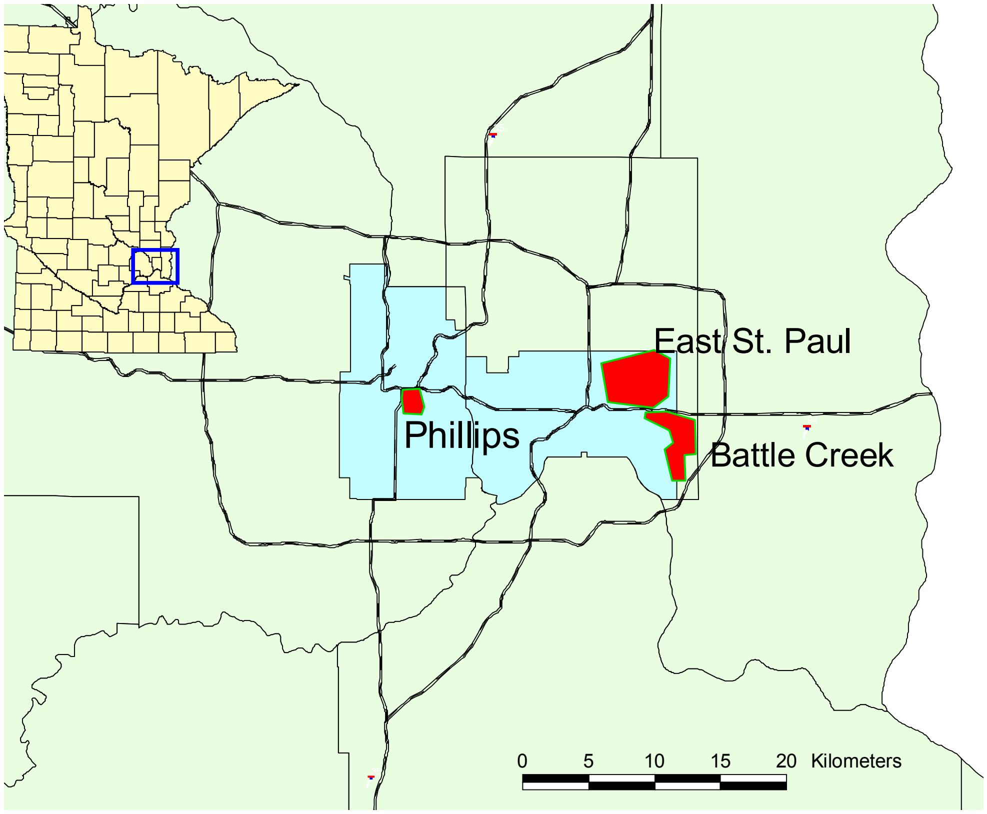

Figure 1. Map of neighborhoods selected for monitoring.

1999 HAPS Monitoring Schedule

48hr / 3 Day Monitoring Schedule

January 99

SUN	MON	TUE	WED	THU	FRI	SAT
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

February 99

SUN	MON	TUE	WED	THU	FRI	SAT
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28						

March 99

SUN	MON	TUE	WED	THU	FRI	SAT
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

April 99

SUN	MON	TUE	WED	THU	FRI	SAT
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20v	21	22v	23v	24
25v	26v	27	28v	29v	30	

May 99

SUN	MON	TUE	WED	THU	FRI	SAT
						1v
2v	3	4v	5v	6	7v	8v
9	10v	11v	12	13v	14v	15
16v	17v	18	19v	20v	21	22v
23v	24	25v	26v	27	28v	29v
30	31v					

June 99

SUN	MON	TUE	WED	THU	FRI	SAT
		1v	2	3v	4v	5
6v	7v	8	9v	10v	11	12v
13v	14	15v	16v	17	18v	19v
20	21v	22v	23	24v	25v	26
27v	28v	29	30v			

July 99

SUN	MON	TUE	WED	THU	FRI	SAT
				1v	2	3v
4v	5	6v	7v	8	9v	10v
11	12v	13v	14	15v	16v	17
18v	19v	20	21v	22v	23	24v
25v	26	27v	28v	29	30v	31v

August 99

SUN	MON	TUE	WED	THU	FRI	SAT
1	2v	3v	4	5v	6v	7
8v	9v	10	11v	12v	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

September 99

SUN	MON	TUE	WED	THU	FRI	SAT
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23v	24	25v
26v	27	28v	29v	30		

October 99

SUN	MON	TUE	WED	THU	FRI	SAT
					1v	2v
3	4v	5v	6	7v	8v	9
10v	11v	12	13v	14v	15	16v
17v	18	19v	20v	21	22v	23v
24	25v	26v	27	28v	29v	30
31v						

November 99

SUN	MON	TUE	WED	THU	FRI	SAT
	1v	2	3v	4v	5	6v
7v	8	9v	10v	11	12v	13v
14	15v	16v	17	18v	19v	20
21v	22v	23	24	25	26	27
28	29	30				

December 99

SUN	MON	TUE	WED	THU	FRI	SAT
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

V Saturday or Sunday MPCA Site Visit

24hr Run Days

V Site visit:Collect/Setup PM2.5,PM10,VOC, Hang VOM Badge

V Site visit to Remove VOM Badge

note: VOC samples run 48 hrs starting at 8 pm prior to the midnight of the 24-hr run da

Figure 2. Calendar of sampling periods

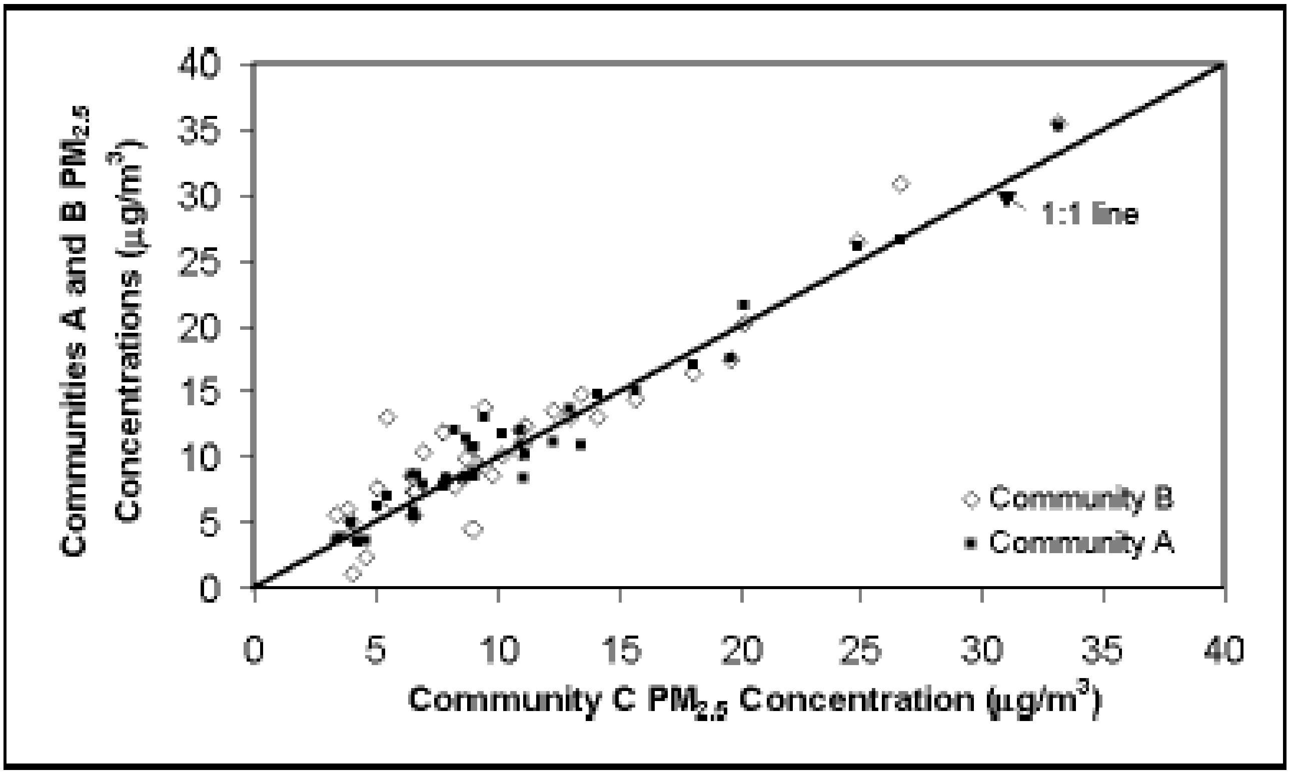

Figure 3. Outdoor PM2.5 concentrations measured at central sites in communities A (n = 45) and B (n = 50) plotted against those measured at community C (n = 44). A linear regression of community A vs community C had an R^2adj = 0.90 with a slope of 1.00 (±0.05). A linear regression of community B vs community C had an R^2adj = 0.95 with a slope of 1.00 (±0.04). A linear regression of community B vs community C had an R^2adj = 0.89 with a slope of 0.94 (±0.05). For all three regressions, the intercepts were not significantly different from zero.

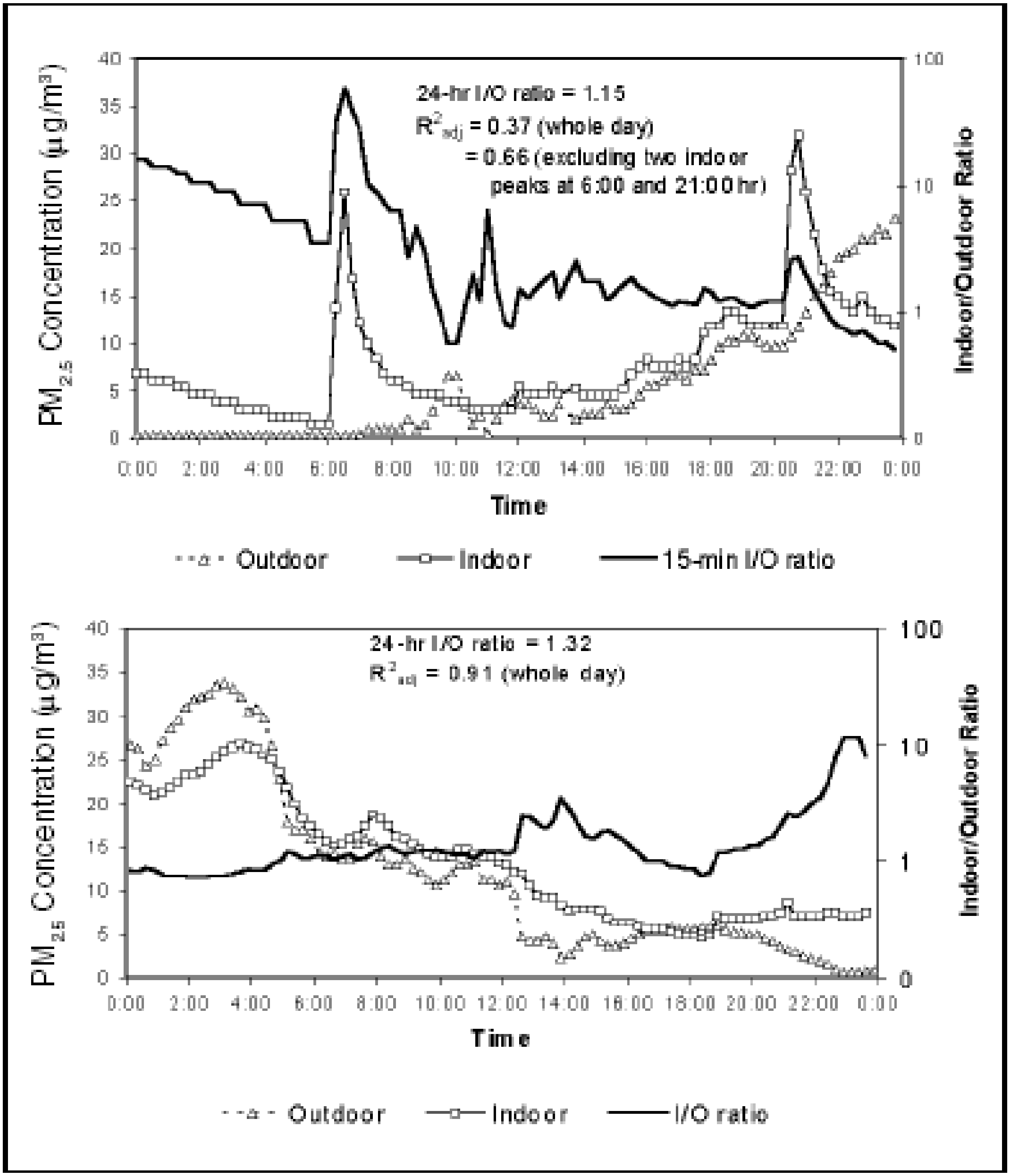

Figure 4. (a) Real-time outdoor and indoor PM2.5 concentrations and I/O ratios over one day in a residence. There were two distinct periods when the indoor concentration showed a sharp spike, around 7:00 a.m. and around 9:00 p.m. (b) Real-time outdoor and indoor PM2.5 concentrations and I/O ratios over one day in a residence. Indoor PM2.5 levels closely tracked the outdoor levels, and there were no indoor concentration spikes.

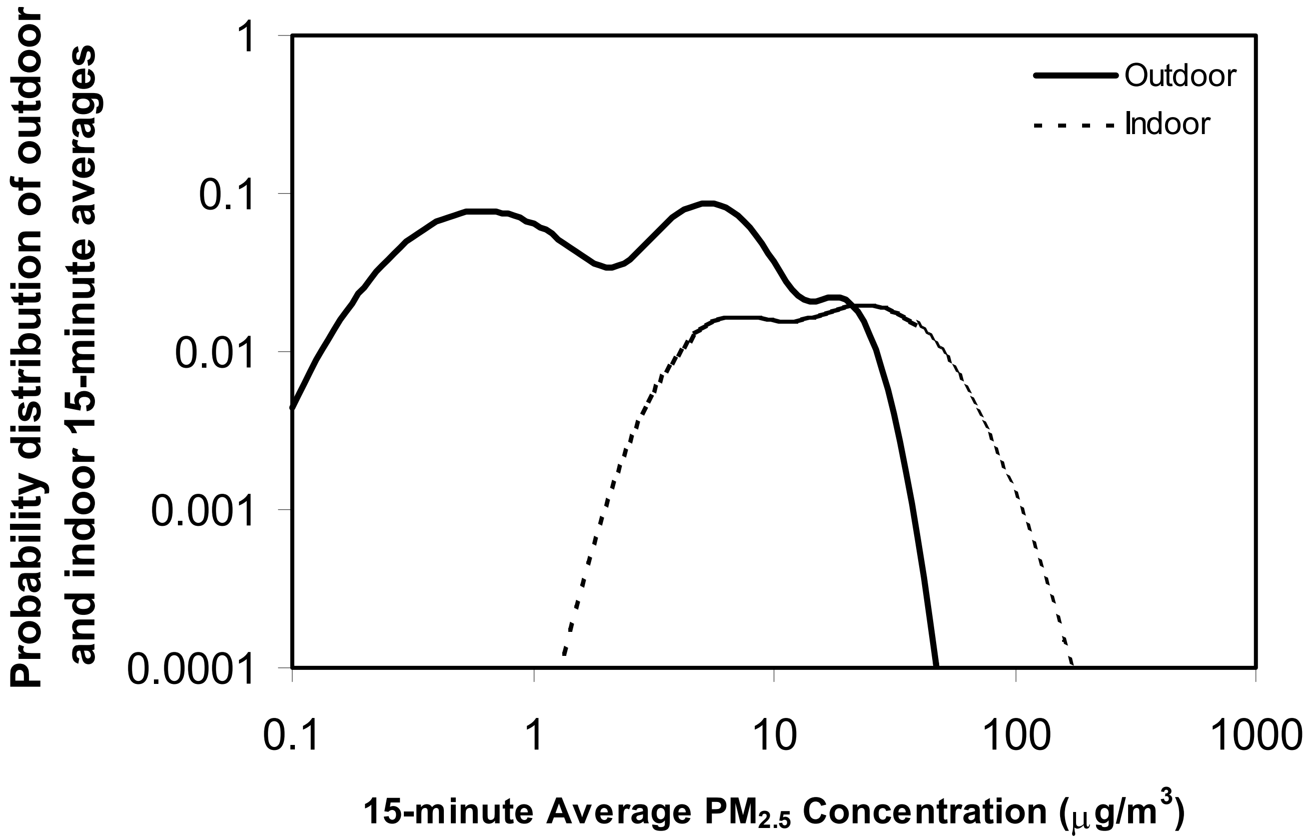

Figure 5. Probability distributions of outdoor and indoor 15-minute average $PM_{2.5}$ concentrations in indoor and outdoor air. The outdoor air shows a trimodal distribution; whereas the indoor air shows a bimodal distribution in which the low concentration "clean" mode is absent and the high concentration "dirty" mode is enhanced.

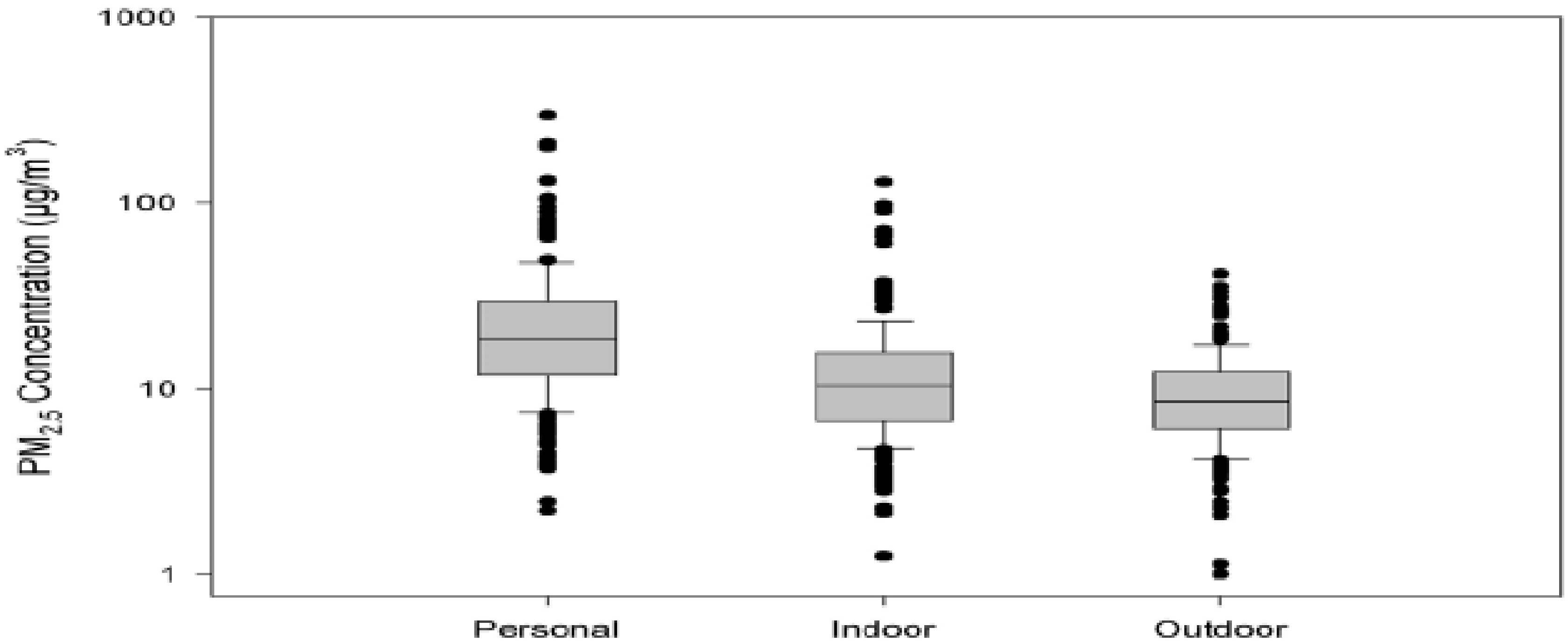

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Figure 6. Box plot of Personal, Indoor and Outdoor $PM_{2.5}$ concentrations (µg/m^3) for all communities and seasons. Boxes indicate mean, inter-quartile range, and dots indicate values outside that range.